

Cavity and coupler design

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Outline:

Cavity RF design and specifications

Lorentz forces

Cavity vertical test upgrade

Coupler RF design, power consumption

Coupler Thermal and MP calculations

Coupler processing test stand

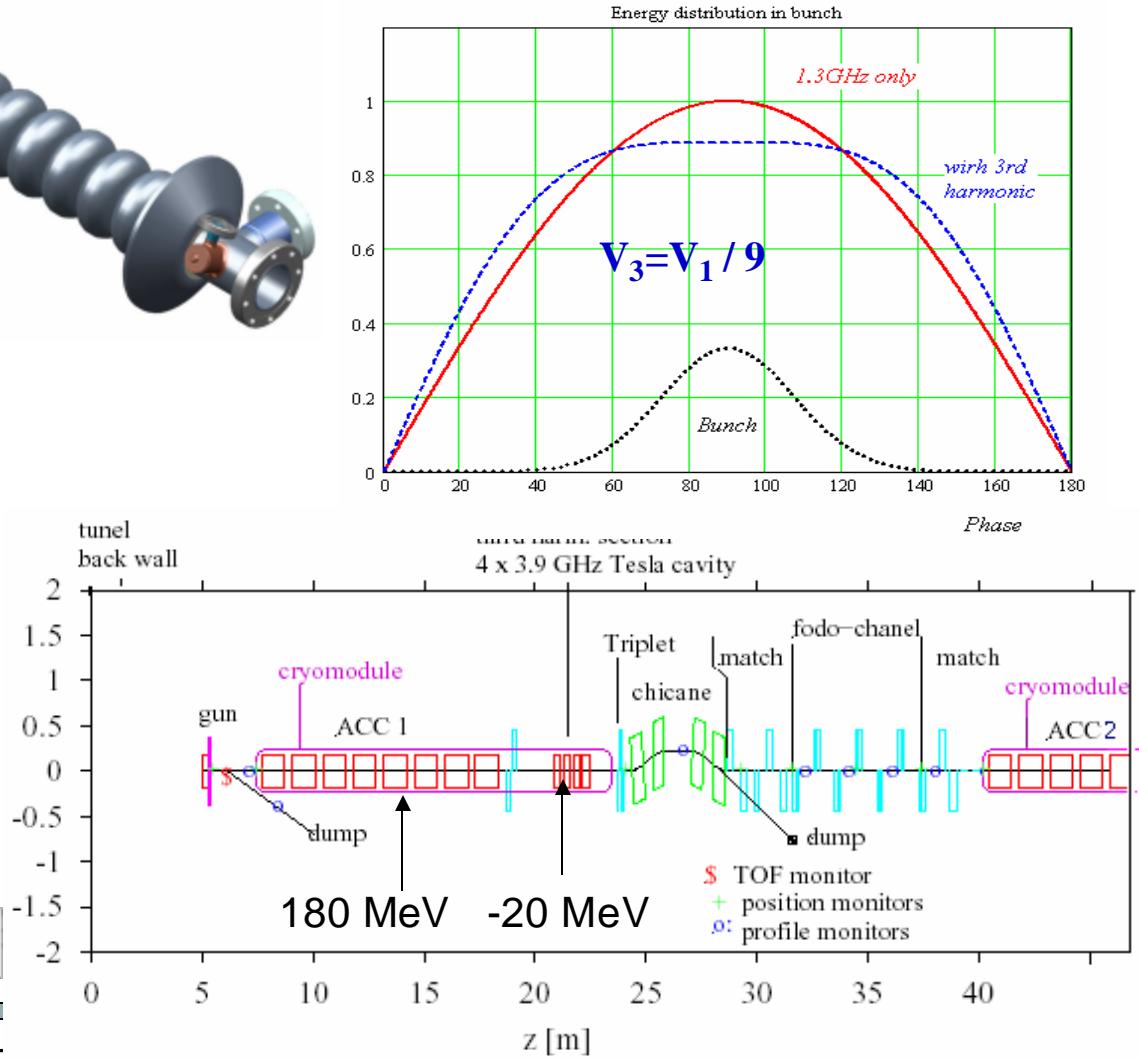
Cavity General Parameters

Third harmonic cavity (3.9GHz) was proposed to compensate nonlinear distortion of the longitudinal phase space due to cosine-like voltage curvature of 1.3 GHz cavities.

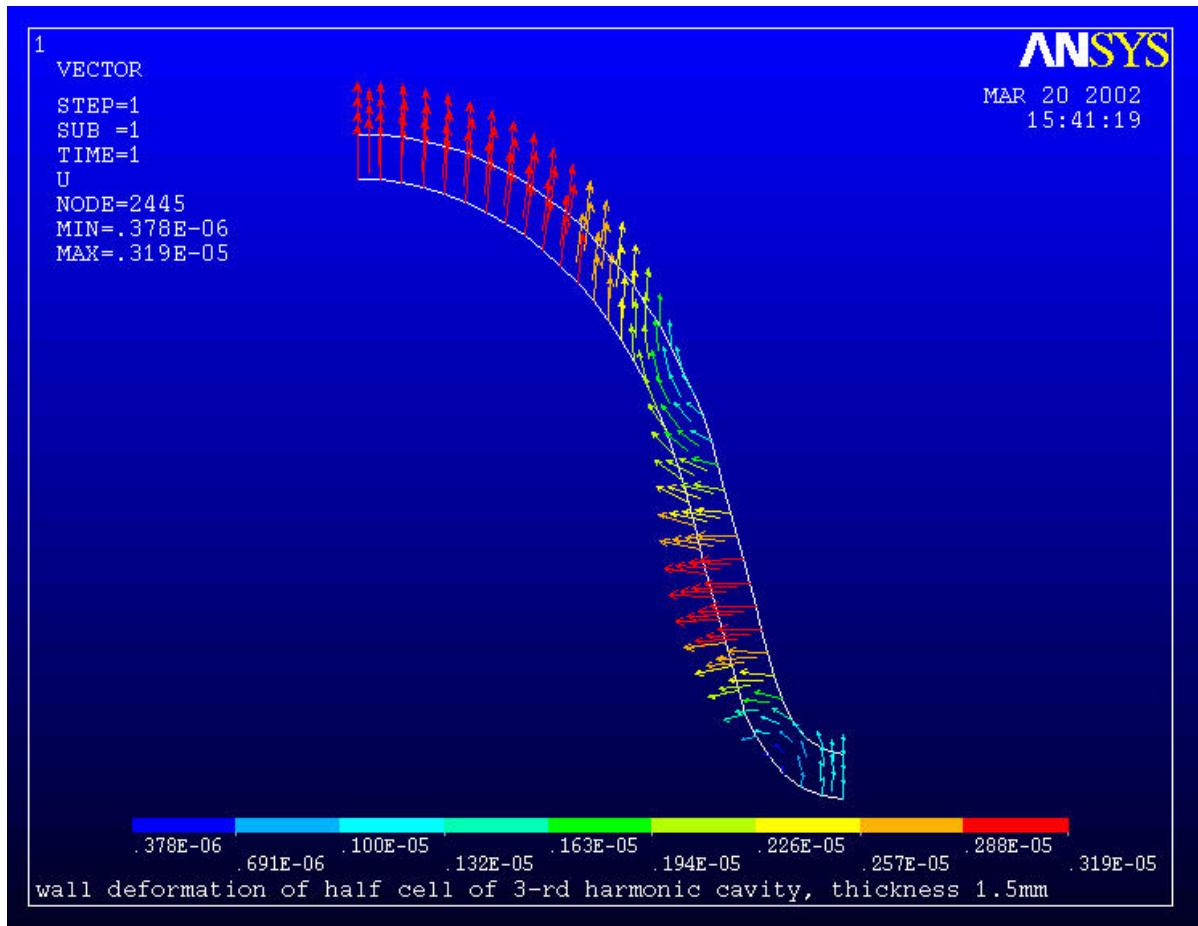


Parameter List for 3.9 GHz cavity:

Number of cavities	4
Active Length	0.346 m
Gradient	14 MV/m
Phase	-179 deg
R/Q	750 Ω
$E_{\text{peak}} / E_{\text{acc}}$	2.26
$B_{\text{peak}} (E_{\text{acc}}=14 \text{ MV/m})$	68 mT
Q_{ext}	$9.5 \text{ e}+5$
BBU limit for HOM, Q	$<1.\text{e}+5$
Total energy	20 MeV
Beam current	9 mA
Forward Power	11.5 kW
Coupler power	45 kW



Frequency shift due to Lorentz forces.



Displacement of the cell wall due to Lorentz force.
Wall thickness T=1.5 mm.

- HFSS simulation of half cell
 - $P = (\mu_0 H^2 - \epsilon_0 E^2)/4$
 - data exchange (HFSS-ANSYS)
- ANSYS simulation of stresses in half cell
 - different wall thickness
 - Yung modulus, Poisson's ratio
- Frequency shift due to Lorentz force (Slater's Theorem)

$$\Delta F = F / (4W) \int_{\Delta V} (\epsilon_0 E^2 - \mu_0 H^2) dV$$

$$E_{acc} = 15 \text{ MV/m}$$

Wall thickness ΔF

1.5 mm	200 Hz
2.8 mm	90 Hz

Cavity bandwidth \approx 4kHz
No stiffening rings.

Vertical test stand upgrade at A0

For cavity vertical tests the existing A0 vertical test stand will be used.

Few minor modifications:

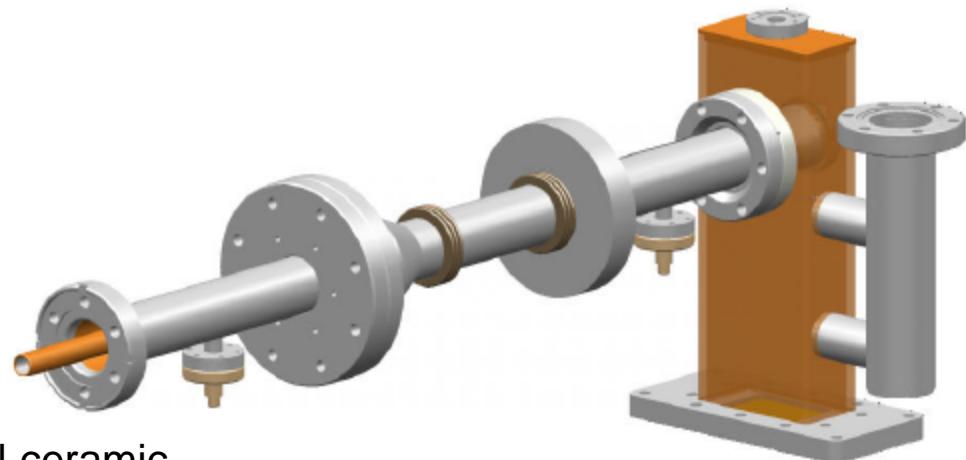
- Support flanges and new roads
- Cavity - tube transitions
- Increase RF power $P \sim 300$ W (CW)
(3kW CW klystron will be install)
- Second set of coupler and pick-up antenna to reduce preparation time for the next cavity



Coupler RF design

Main features

- Ø30mm/ Ø13mm coaxial line
- Standard copper waveguide
- Fix coupling
- No DC biasing
- Cold window: DESY TTF3 cylindrical ceramic
- Warm window: CPI 3.9 GHz WG window
- Two sets of bellows (flexibility)
- All internal parts are copper plated (30 μm inner and 10 μm outer part of coax)
- All part are brazed
- Pick-ups and glass window for diagnostics
- Good pumping performances



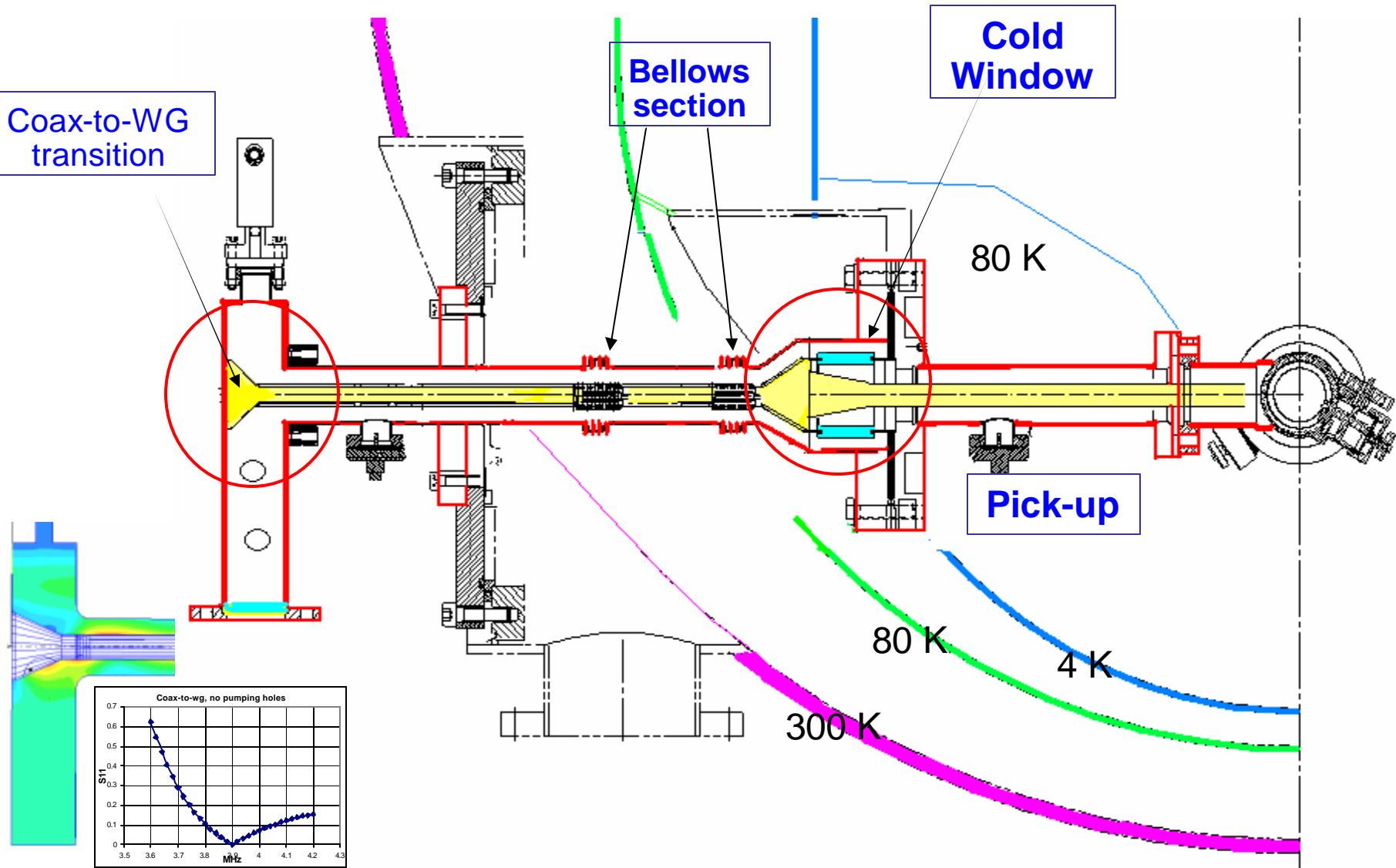
$P_{\text{peak}} = 45 \text{ kW}$ ($I_b = 9 \text{ mA}$)

(processsing at 80kW)

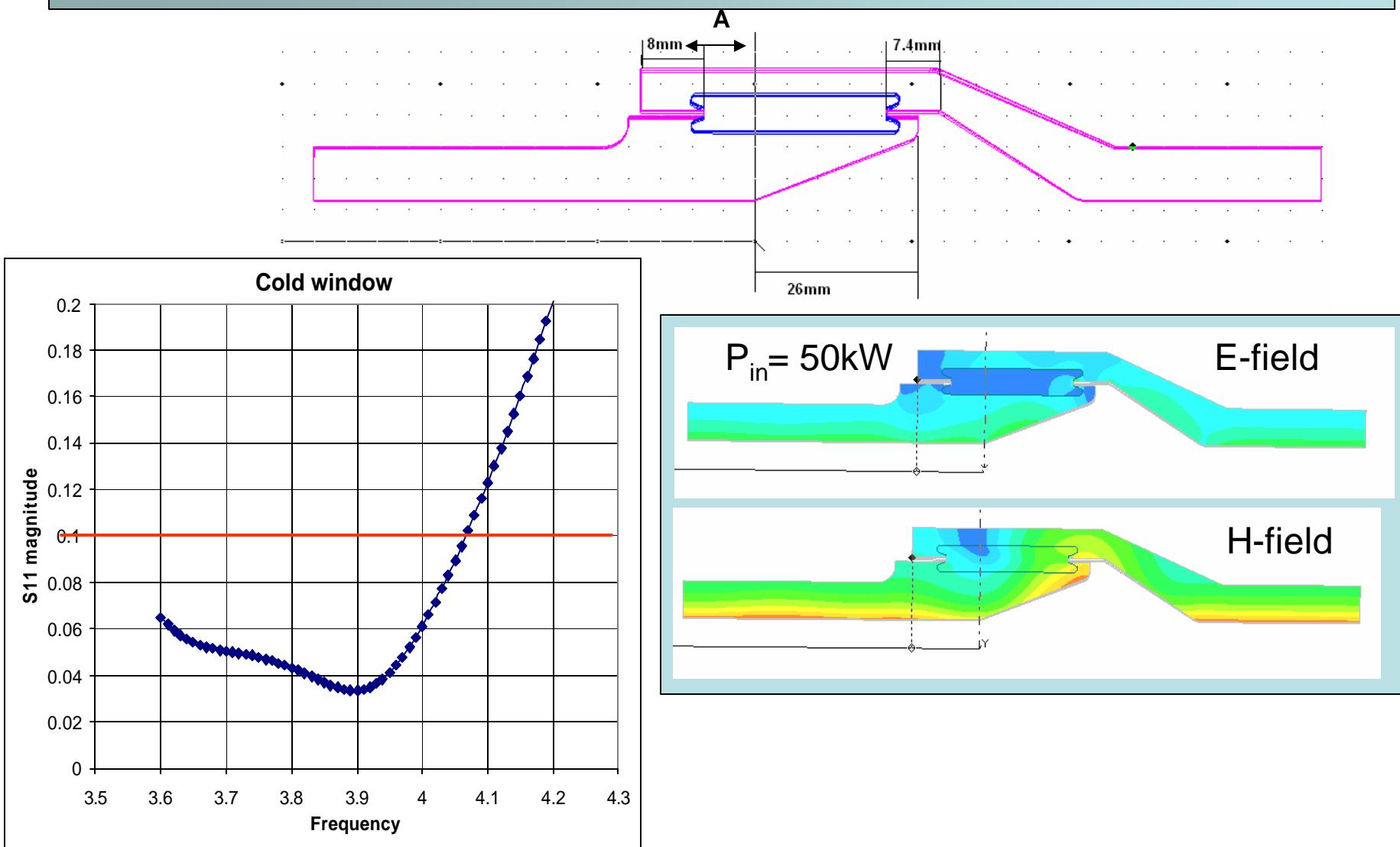
Pulse = 1.3 ms

Rep. rate = 5Hz

Coupler cut view



Cold Window RF design



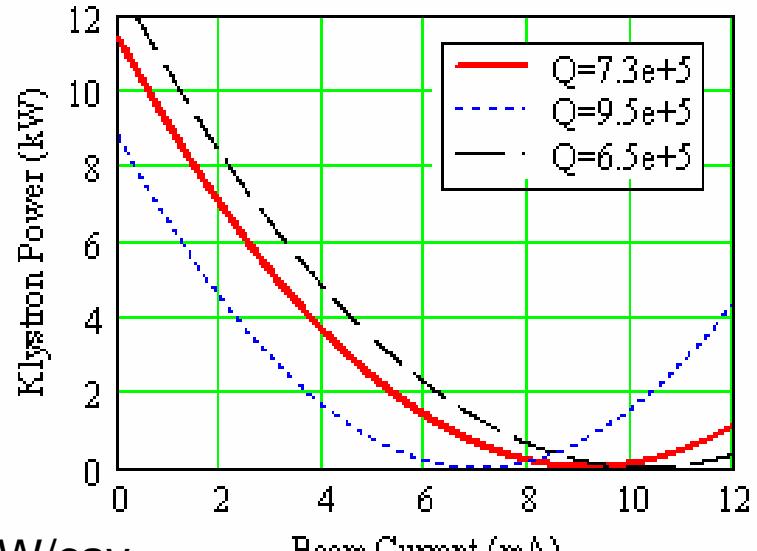
Coupler Power consumption

Power from klystron:

$$P = \frac{V^2}{4(r/Q)Q_L} \left[\left(1 + \left(\frac{r}{Q} \right) Q_L \cdot \frac{I}{V} \cos f \right)^2 + \left(\tan y + \left(\frac{r}{Q} \right) Q_L \cdot \frac{I}{V} \sin f \right)^2 \right]$$

Where: $(r/Q)=750 \text{ Ohm}$, $V= 5 \text{ MV}$, $y=0$, $f=-179^\circ$

$I_{\text{beam}} \setminus Q_L$	$Q_L=6.65*10^5$	$Q_L=13.3*10^5$
$I = 0 \text{ mA}$	12.5 kW (12)	6.25 kW (6.25)
$I = 8 \text{ mA}$	0.5 kW (40.5)	-2.25 kW (42.25)
$I = 10 \text{ mA}$	0 kW (50)	-6.25 kW (56.25)
$I = 12 \text{ mA}$	-0.5 kW (60.5)	-12.3 kW (72.3)



Parameters for 3.9 GHz cavity
(optimized for 9mA current):

Forward power for 4 cavities	46 kW
Losses waveguide, 50m, 1.1dB	14 kW
Losses circulator, 0.2 dB	3 kW
Regulation reserve 25%	17 kW
Klystron power	80 kW

$$P=11.5 \text{ kW/cav}$$

$$Q_{\text{ext}} = 9.5*10^5$$

(at $t \gg 150 \mu\text{s}$)

$$P_{\text{klystron}}(9\text{mA}) = 0$$

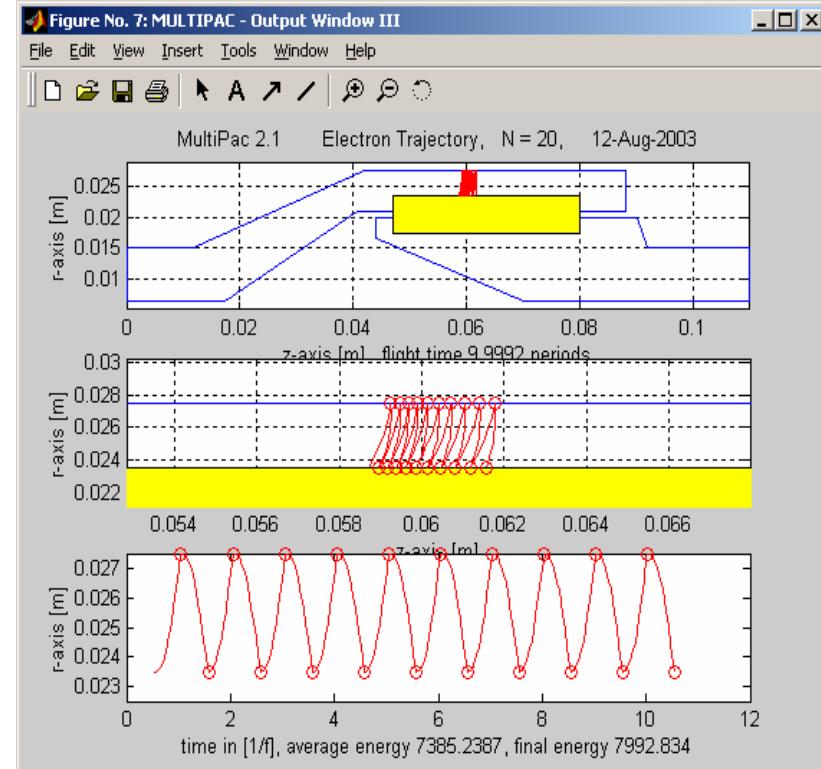
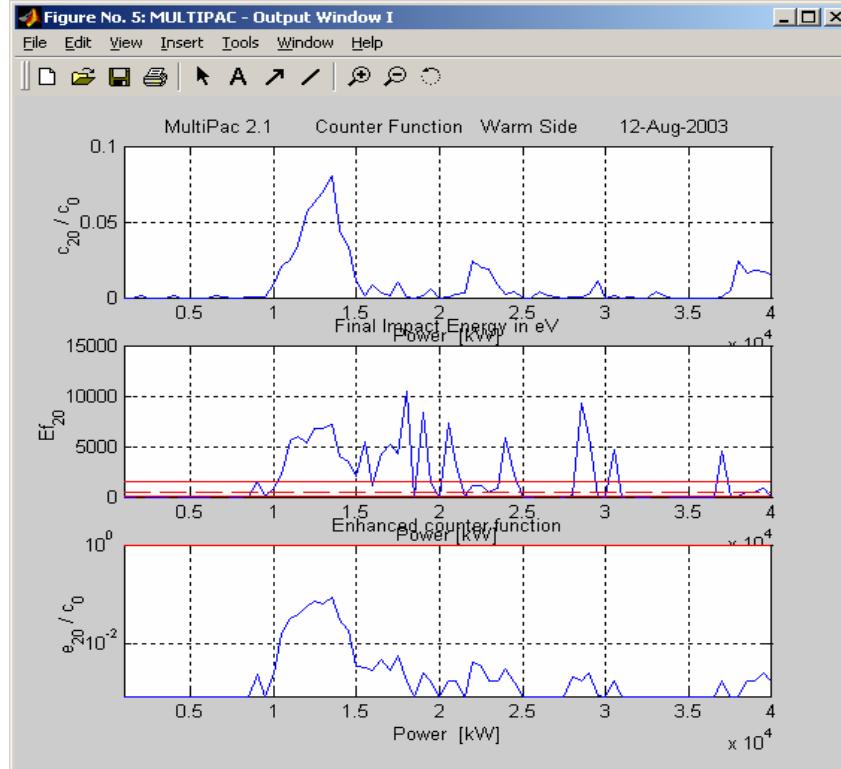
$$P_{\text{coupler}}(9\text{mA}) = 46\text{ kW}$$

Multipactor in coupler

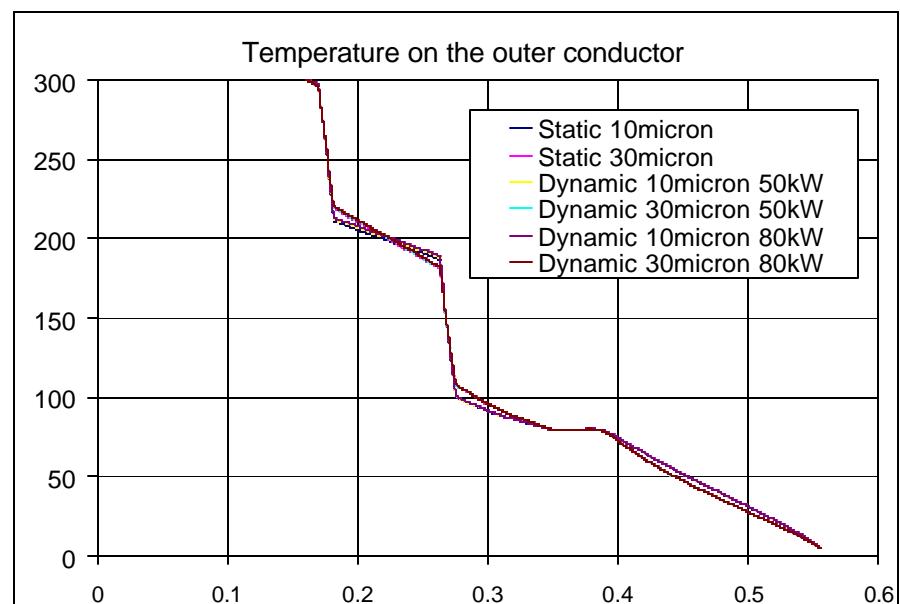
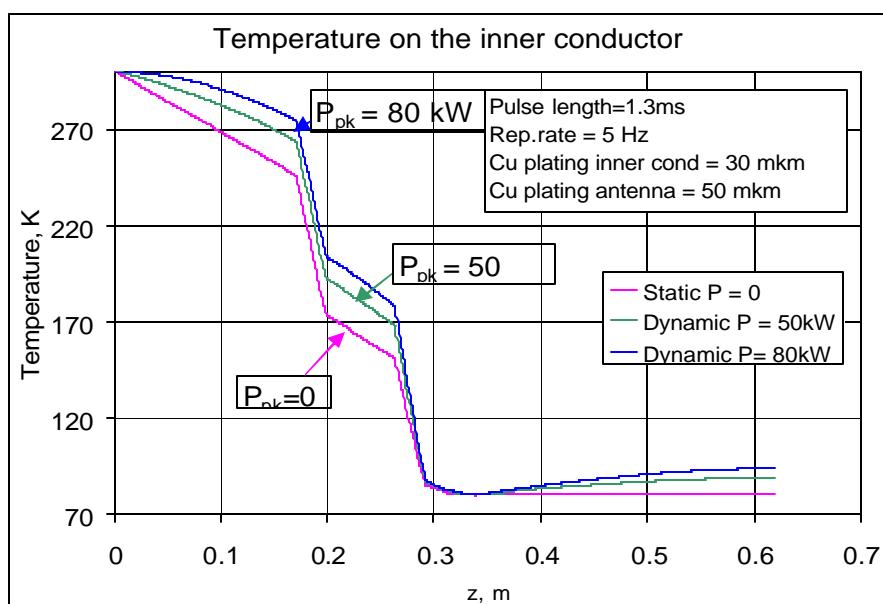
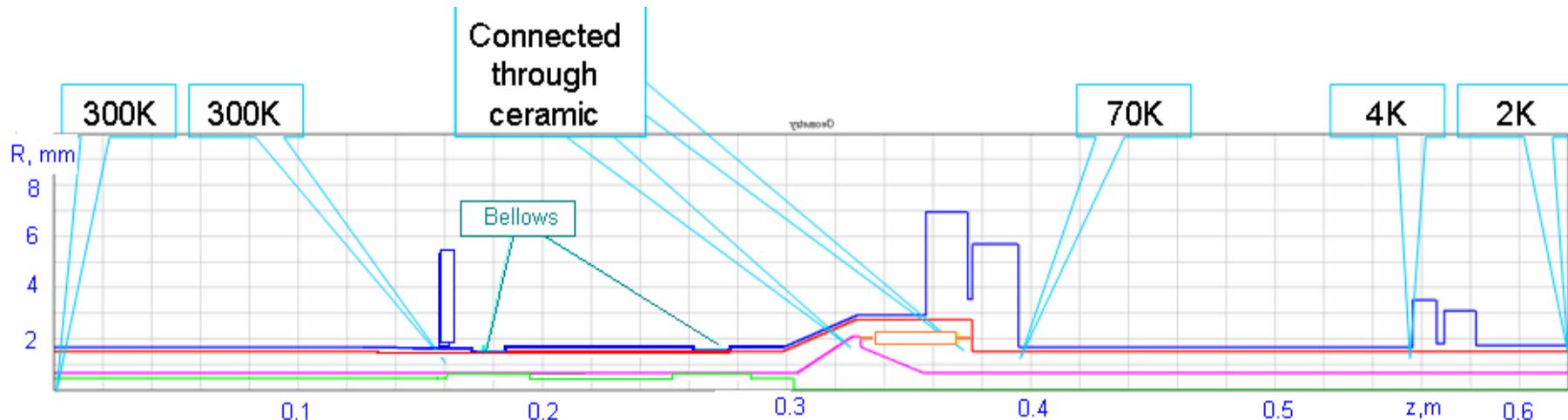
In TTF3 coupler MP is responsible for long processing time. In calculation MP activity starting from ~40kW in coaxial line. Experimentally MP levels found around: 150, 250, 450kW.

MP scales as: $P \sim Z^*(df)^4$, F -frequency, d -coax diameter, Z =impedance.

For 3.9GHz coupler MP threshold is higher by factor of 25 ($P \sim 1\text{MW}$)

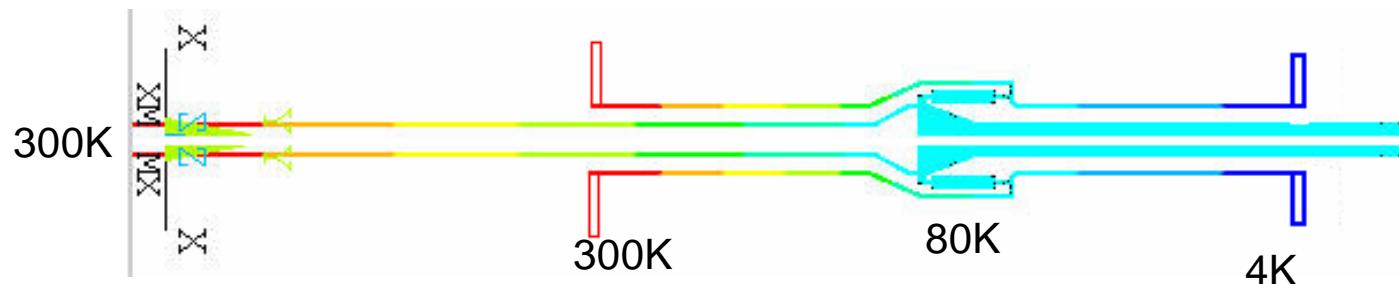


Coupler Thermal calculations



Coupler thermal calculations (Cont.)

3.9 GHz coupler: coax.part. Inner surface 30 mm Cu RRR=10.
Drive Power: 50kW * 5Hz * 1.3ms



Power[kW]	oCu[μm]	Tant (K)	2K	4.5 K	80K (in)	80K (Out)	80K(cer)	80K (Total)
0	10	80.62	0.34	0.016	0.43	0.49	0	0.92
0	30	80.59	0.34	0.046	0.43	0.66	0	1.09
50	10	89.03	0.34	0.017	0.72	0.50	0.10	1.32
50	30	88.93	0.34	0.047	0.72	0.68	0.10	1.38
80	10	94.06	0.34	0.017	0.90	0.51	0.16	1.57
80	30	93.94	0.34	0.047	0.90	0.67	0.16	1.73
50	0	89.0	0.31	0.43	1.36	2.7	0.10	4.16

Coupler HP processing

- ★ Coupler parts are cleaned at A0 clean room
- ★ Coupler cold parts are assembled in the class 10 clean room, warm part- in class 100 room
- ★ Before RF test couplers are baked ~2 days at T=150°C.

Diagnostics:

- Forwarded and reflected (amplitude and phase)
- 4 pick-up signals: 2 from each coupler + cavity
- 2 Light detector,
- 4 temperature control
- Vacuum pressure (high vacuum gauge) in 3 points

Coupler processing limits:

- e- pick-up IL signal: 5 mA
- Light (PM) IL signal: 1 Lux
- Vacuum pressure: 10-6 mbar
- Ceramics temperature: 85°C
- WG sparks: stop if any

LLRF and data acquisition and control system:

Most part of the system, developed for CC2 will be used
1FTE*month +10k\$ update to 3.9GHz

Schedule: 3 tests, ~10 days/test +3 days assembly

FTE's: (2Eng + 1Tech)*month, not includes FTE's for
RF power and LLRF and control system

Coupler processing procedure:

Pulse Length [μs]	20	50	100	200	400	800	1300
Peak Power [kW]	Max 80kW (increasing rate 0.2dB/min)						

